A Knowledge Management Framework to Promote Infrastructure Project Sustainability

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***Abstract* — Infrastructure development can cause major impacts on our environment, society and local economy. As the global realm of sustainability develops and evolves, it is increasingly accepted that sustainability issues should be put on top of the agenda when contemplating infrastructure development. While many construction organizations will not argue against pursuing sustainability, in practice problems often lie with what should be done, who should do them and how mutual benefits can be obtained. This is compounded by the fact that very often there are no common understandings between the stakeholders, and the gap between advancement of research and real life applications in actual projects is still significant. New approaches should be investigated to both develop and expand the body of sustainability knowledge on infrastructure development and investigate better ways of communicating with and managing it to overcome the various barriers within the sector.**

Knowledge management (KM) has shown its worth and promise in existing applications in the construction industry. Various attempts are being made to develop tools and mechanisms for the effective management of construction knowledge yet few are capable of handling specific characteristics associated with sustainability concerns and infrastructure works. An ongoing research project, undertaken by Queensland University of Technology in Australia, is introduced in this paper. It enlists two rounds of industry surveys to study the unique characters of infrastructure development as well as how sustainability knowledge is best shared and managed. A holistic KM approach is proposed to facilitate sustainability knowledge creation, capture, sharing and application, and the whole process is encapsulated in a general KM framework for decision making of infrastructure stakeholders. It is expected that this research will build up the links between KM activities, industry environment and organizational performance.

Keywords- Sustainability, Infrastructure, Knowledge Management, Project Management

I. INTRODUCTION

Infrastructure in the Australian context typically includes utilities and facilities such as roads, ports, rail, power lines, water pipes, power generation buildings, sewer plants, and other tangible structures. They work as a holistic system to provide the basic support for urban activities, playing a fundamental role in determining the efficiency and productivity of the Australian economy. As the result of the previous period of strong growth in regional economy, export, and population shift, the demand for infrastructure is creating bottlenecks for economic development in Australia. Regeneration of existing infrastructures and developing of new infrastructures are on the top agenda around the world (Asia Development Bank, 2003). More recently, infrastructure development has taken centre stage following the global financial crisis and the resulting economic downturn. Governments around the world have embarked on major infrastructure investments to cushion, if not reverse, the rapid slump into recession (KPMG, 2009).

In Australia, the recent Australian Federal 2009-10 budget significantly increased infrastructure spending, and more than $22 billion will be invested for "Nation Building Infrastructure". As part of that, the commonwealth is committing $8.5 billion towards 'nationally significant' infrastructure projects with an estimated work value above $35 billion (Australian Government, 2009).

It has also been clearly indicated by the government and well accepted by various stakeholders that the development of infrastructure to improve standard of living and competitiveness must not come at the expense of the environment and social objectives (Infrastructure Australia, 2008). As the development process of infrastructure can have significant disturbance to the natural environment and local and regional planning, span over a long duration and consume significant amount of resources, drawing close all relevant

facets of sustainability issues and 'do things right' is a big challenge when contemplating the infrastructure roadmap.

Moreover, at the organizational and real project levels, substantial improvement is required for sustainability measures and application. To many practitioners, sustainable development itself may still be a vague and evolving concept. There is a lack of consensus on sustainability among infrastructure professionals and stakeholders, who are from diverse disciplines with different point of views (Yang and Lim 2008). Pathriage et al argue that the construction needs to intensify its efforts to move to a knowledge intensive mode as better decision-making towards sustainability goals can only be achieved if the stakeholders are informed the latest concept, knowledge and expertise across organizational, professional and hierarchical boundaries (2007).

The purpose of this paper is twofold. First, it is to review and assess the knowledge being used to promote infrastructure sustainability. Second, it will describe a specific knowledge management approach to facilitate sustainability knowledge creation, capture, sharing and application. This whole process is encapsulated in a general KM framework for decision making of infrastructure stakeholders.

II. SUSTAINABILITY AND INFRASTRUCTURE: A KNOWLEDGE-BASED PERSPECTIVE

Sustainability goals can only be achieved if construction activities are informed and directed by new resources and expertise. Some of this comes in the form of good practice, standards and enhanced process models, but much will have to come from situated and contextual appreciations of sustainability goals and local practices developed across organizational and professional boundaries (Pathirage *et al*., 2007).

Although knowledge can be borrowed from other sectors (e.g. green building) and industries, infrastructure professionals are not in a position to "cut and paste" best practice from the past due to the very unique and the complex nature of the infrastructure projects. They have to draw on the past knowledge to find solutions to the future.

In this research context, "sustainability knowledge" is defined as the type of knowledge which improves the sustainability of an infrastructure project during its life cycle. Three important types of sustainability knowledge are listed in Table 1 as examples, which are assessment tools, government guidelines/polices and project experiences.

	Project Experiences	Government Guidelines/ Polices	Assessment Tools
Location	Individuals	External resources	External resources
Type	Explicit/tacit	Explicit	Explicit
Character	Mostly reside in people minds; Hard to track, record and widely share.	Vague and general.	Mainly developed from building assessment tools and still at infant stage.

Table 1. Examples of Sustainability Knowledge for Infrastructure Development

Government legislation and guidelines play important roles in promoting infrastructure sustainability. While they provide the industry with a sense of direction and useful tips, they are often vague and too general for organizational and project level applications.

In the construction industry, much valuable construction knowledge resides in the minds of individuals working within the domain. It can be very hard to track, record and share widely. Moreover, these individuals who worked on a specific project are likely to leave for other projects at completion; hence their input is not captured for specific applications.

In fact, it was not until very recent years that studies are conducted specifically for infrastructure sustainability. Some criteria, indicators and frameworks were developed for sustainability assessment in order to understand and quantify "how sustainable the infrastructure is" (See for example: Dasgupta and Tam, 2005; Sahely et al., 2005; Ugwu and Haupt, 2007). Most of the assessment tools are derived from building assessment tools such as GREENSTAR, LEED, BREAM and most are limited to the design stage.

For the industry to embrace the sustainable principles, there is an underlying need for technical, social and innovation changes. However, Myers (2005) studied the construction companies' attitudes towards sustainability in the UK and found that very few companies have positively and wholeheartedly embraced sustainable ideas and implemented them in their operations. Review of literatures and some industry feedback to the authors have identified the following reasons:

A. Sustainability knowledge

The concept of sustainability is fluid, dynamic and evolving. Current knowledge and its capture are not mature enough to be implemented in project level.

B. Industry characters

The construction industry by nature has a very

complex structure and it is more so for infrastructure development. It often involves both public and private sectors, uses a variety of financing sources, deploys a combination of procurement methods, and brings forward a number of stakeholders that tend to have fragmentation and low efficiency of communication. Due to their very diverse professional background, stakeholders tend to guard their own interests thus can hold different interpretations on sustainability issues (Ugwu and Haupt, 2007, Yang and Lim 2008).

Furthermore, sustainability issues are complex and need innovative solutions. The demanding and often stressful routines of construction work can result in the unwillingness to learn and develop innovative solutions.

C. Outcomes of Sustainability Input

A business focus is naturally the centre of any organizational initiative and represents the value-adding processes of an organization, which may typically include strategy development, product/service innovation and development, manufacturing and service delivery, sales and customer support. However, links between sustainability uptake and implementation and organization performance are not clear.

Therefore to push for better adoption of and efficiency in delivering more sustainable outcomes in infrastructure projects, there is a genuine desire and mandate to:

- Expand the body of sustainability knowledge;
- Search better ways to trigger knowledge creation, sharing and application across diverse boundaries;
- Provide the industry with intensive and up-to-date knowledge and expertise to promote integrated decision making during sustainable infrastructure development.

Over the recent years, the practice of knowledge management in the construction industry is starting to yield tangible results and the value and potential of this emerging discipline are more and more recognized (Wetherill *et al*., 2007). The aim of this research is to propose a holistic KM approach to facilitate the creation, sharing, storage, and application of sustainability knowledge within the infrastructure sector and provide a platform of best practice for managing the knowledge among all stakeholders involved, and thus promote infrastructure sustainability.

III. KM AND KM FRAMEWORK

Although knowledge management (KM) is a relatively new and emerging discipline, mechanisms and tools have been developed and employed to better manage information and knowledge in diverse contexts in many sectors of industry and business. It is now a broad and expanding topic contributed by diverse disciplines and a multifold mix of strategies, tools, and techniques (Dalkir, 2005). From the functional perspective, KM can be seen as a systematic approach to manage the use of information in order to provide a continuous flow of right knowledge to the right people at the right time enabling efficient and effective decision making in their everyday business (Teece, 2000). That means providing access to information at the time people need it to make the best decisions possible for mission success and efficiency.

There is a general recognition among researchers that knowledge management is a cross functional and multifaceted discipline. While experience has shown that, other than the widely recognized technology issue, socio-cultural issues are often the most difficult to tackle, it is equally important to keep in mind the "bigger picture" – the wider economic, technological and structural issues facing the organization as it strives to innovate faster and within which any corporate KM initiative inevitably takes place. In fact, a variety of components make up knowledge management and the understanding of their relationship is important; a holistic view is very useful.

As a useful tool, KM framework can relate the various components of KM (people, process, technology etc.) to each other and provide a schematic picture of how these various aspects depend on each other and it helps to position KM projects/activities (European Committee for Standardization, 2004). With the explosive growth of information and knowledge across various industries, many different KM frameworks have been produced. For infrastructure sustainability issues, the benefits to gain from a KM framework are aplenty. For example it can provide consistent language, outline a process, provide a checklist, offer a source of ideas and address non-technical aspects.

Past research has emphasized three major elements for managing: processes, enablers and organizational performance (Lee *et al*, 2003). The relationship between the 3 elements can be seen from Figure 1.

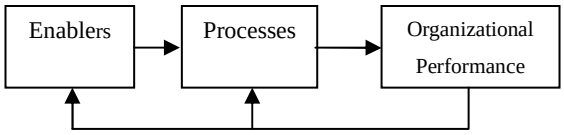

Figure 1, An Integrative Framework for Studying Knowledge Management (Lee *et al*, 2003)

Knowledge process (refers to knowledge management activities, which is frequently called KM cycle in many literatures) can be thought of as a structured coordination for managing knowledge effectively. Typically knowledge managing process

includes activities such as identify, create, store, share and use as the basic operations of knowledge management activities.

Knowledge management enablers (or influencing factors) are organizational mechanisms for fostering knowledge and facilitate the sharing of knowledge in an organization to increases the efficiency of knowledge processes. In some existing frameworks, enablers are identified in two categories: personal knowledge capabilities, which include ambition, skills, behavior, experience, tools and time management, etc., while organizational knowledge capabilities include the mission, vision and strategy, the design of processes and organizational structures, measurement, understanding of the culture, the use of technology and infrastructure, etc.

Organizational performance may be defined as the degree of which companies achieved its business objectives. It may be measured in terms of organizational profitability, organizational learning, competitiveness etc. It is widely accepted that the any KM initiative will need to centre on the business focus and value-adding processes of an organization. But a KM framework needs to consider more aspects for managing sustainability knowledge during infrastructure project development. In consideration of the characteristics of sustainability knowledge as well as this industry sector, the authors propose a specific KM framework with the following key elements.

(1) KM Strategy

KM encompasses a systematic approach to managing the use of information in order to provide a continuous flow of knowledge so as to enable the efficient and effective decision making by key decision makers and is underpinned by a KM strategy which enables an aim and focus for KM activities.

(2) KM Process

Key processes of managing sustainability knowledge to the requirement of infrastructure development need to be identified.

(3) Stakeholder Integration

Stakeholders often have a great deal of influence on the uptake and application of sustainability knowledge. Quality decisions can be reached if stakeholders are kept to date about the most recent concepts and technology. Interactions between stakeholders on project sustainability issues are particularly important.

(4) Project Development Process

Formulating project sustainability conception and their applications are closely intertwined with project developing processes. Thus knowledge managing activities should also be linked with PM processes.

(5) Knowledge Architecture

Knowledge architecture refers to the body of sustainability knowledge, its classification, characteristics etc. which need to be considered while choosing the appropriate KM strategy and approaches.

(6) KM Enablers

Many factors can influence the success of knowledge management initiatives within an organization. For many existing KM framework, enablers are usually categorized into 2 groups, organizational and personal. However, construction organizations are highly project-originated and have a high staff turnover within the industry. Capabilities within the organization as well as the project team are important aspect in the framework.

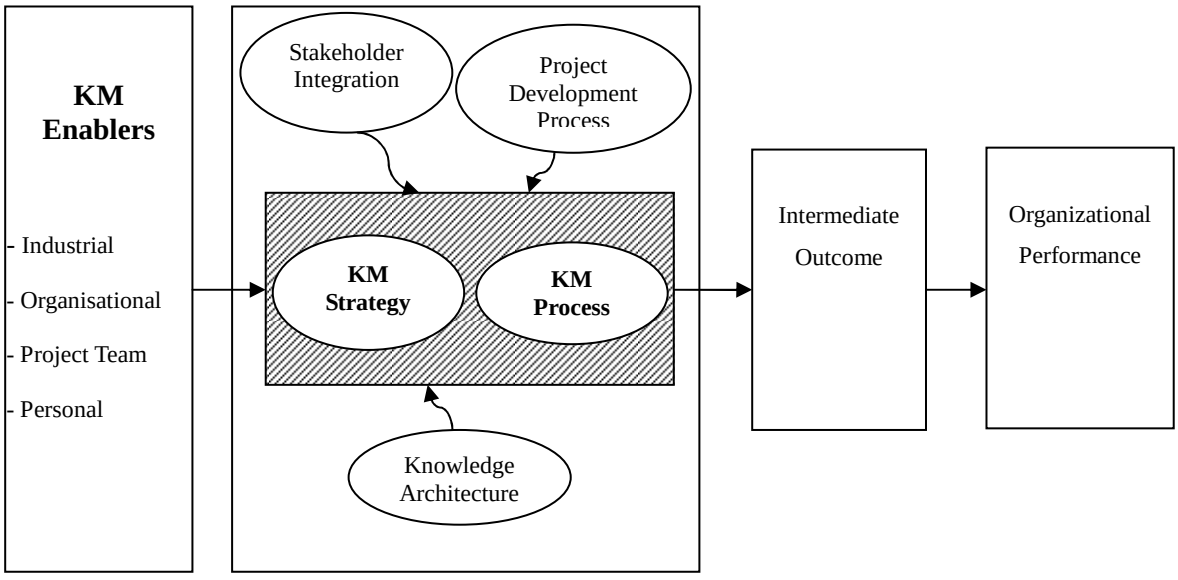

Figure 2, A KM Framework Prototype for Sustainable Infrastructure Development

(7) Intermediate Outcomes & Organizational Performance

KM initiatives needs to link to the organization's business goal. The outcomes of managing sustainability knowledge and improvement of organizational performance through knowledge management are key issues.

To identify ways of applying knowledge management to increase sustainability consideration and uptake in infrastructure development, a questionnaire survey has been conducted to gauge the status and opinions of Australian infrastructure professionals on how they interpret the KM concept and its various aspects in order to test and further identify the key elements of this KM framework as well as the relationship amongst them. The survey design is introduced in the following section.

IV. THE QUESTIONNAIRE SURVEY AND ON-GOING RESEARCH

A structured questionnaire, running to 9 sections and having 37 questions, was framed according to the key elements of the framework prototype to collect responses. The respondents represent the key stakeholders of infrastructure were carefully selected from various types of organizations involved in infrastructure development from both private and public sectors across Australia. These organizations include architectural firm, engineering firm, consulting firm, supplier, general contractor, sub-contractor, consulting firm and government agency etc. The structure of the questionnaire can be seen from table 2.

130 questionnaires have been sent out directly to the identified infrastructure experts (experienced project managers, designers, business managers etc.) in these organizations through a web-based survey tool. Mail-out of questionnaires was also made to those without computer access.

To date, the authors have received over 40 valid questionnaires. A 30%+ response rate is expected. Information extracted from the survey will be used to identify the key elements of appropriate processes/ approaches/ methods for the construction organizations to manage sustainability knowledge. A preliminary KM framework will be generated base on the results. Afterwards, selected cases studies will be conducted to verify this preliminary framework and to generate the final development which will include formulation of contextual and visual representation of the final framework and the development of application guidelines, a procedure-driven "how to apply" operational manual.

	Category	Questions
1	General Respondent Information	Q1-Q7 This section collects basic information to classify respondents, e.g. professional role in infrastructure, length of professional experience, type of organizational, etc.
2	The Body of Sustainability Knowledge	Q8-Q11 This section collects professional opinion on current sustainability knowledge according to their experience and expertise. Such as the main knowledge categories, knowledge quality, main knowledge carriers, main knowledge characteristics, etc.
3	KM Strategy	Q12-Q20 This section collects information to identify the appropriate KM strategy for the sustainability knowledge management. Such as the current means to manage sustainability knowledge, width and depth of current knowledge application, main impetus and main barriers of such activities, etc.
4	Stakeholder Integration	Q21-Q22 In this section, information is collected concerning the interaction between stakeholders (contractor, subcontractor, project manager, designer, quantity surveyor, engineer, local community, consultant, research institution, government agency, etc) and project sustainability issues, e.g. who are the important stakeholders and their willingness to promote project sustainability, etc.
5	Project Development Process	Q23-Q24 In this section, the stages of a typical life cycle of an infrastructure project are delineated. Information is collected on how project sustainability related activities link with these processes and what are the key sustainability related actions/deliverables.
6	KM Process	Q25-Q31 Information is collected to identify those processes specific to manage sustainability knowledge for infrastructure development among the typical KM processes. Current status of knowledge management activities inside the organization is also been searched.
7	KM Enablers	Q31-Q35 This section collects information to identify those factors which help to formulate a positive environment for knowledge management success. Enablers are labeled separately as industrial characteristics, organizational capabilities, project team characteristics, personal

	Category	Questions
		capabilities according to their incidence.
8	Outcomes of Managing Sustainability Knowledge	Q36 This section researches what outcomes could be obtained by managing sustainability knowledge, e.g. judgment, reusable content created, value delivery, presence of subject matter expertise, organizational creativity, employee loyalty, etc.
9	Organizational Performance	Q37 This section researches what aspect of organizational performance will be improved by managing sustainability knowledge, e.g. profit, market share, organizational reputation, customer recognition, intellectual asset, etc.

Table 2 Questionnaire Structure

V. CONCLUSION

Infrastructure development is facing a great challenge to support the sustainability agenda. The lessons learned by other sectors of the construction industry and recurring theme of many past research highlight the need for the infrastructure sector to change from its traditional fragmented processes towards a more knowledge intensive mode and bring the stakeholders to common level of understanding on sustainability issues and measures.

As a response to such challenge, a holistic knowledge management (KM) approach has been considered by the authors as a possible solution to help the industry to develop and expand the body of sustainability knowledge on infrastructure development, and providing better communication and decision support through managing the knowledge within the sector. To do this, KM frameworks show the potential as an integrated solution. Based on the current theoretical frameworks, a prototype KM framework has been developed, considering the specific characteristics of sustainability knowledge and the infrastructure sector. Furthermore, a questionnaire survey is being conducted to explore appropriate levels of knowledge and identify issues that impact on knowledge take-up and transfer. Based on this, on-going work will produce a KM framework for the integration between key stages of decision making during the development of infrastructure projects. It is hoped that, with keen participation of industry partners, this approach will ultimately promote the sustainability agenda among all involved in the large and complex projects of infrastructure.

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